Financial and Environmental implications of the Food Bank incorporating the woody biomass as a heating system for their new complex

A Project Submitted to the College of

Graduate Studies and Research

In Partial Fulfillment of the Requirements for the

Degree of Master of Sustainable Environmental Management

In the School of Environment and Sustainability

University of Saskatchewan

Saskatoon

By

Raphiat M. Oladele, MSEM candidate

Project Advisors: Thomas J. Allen and Kenneth W. Belcher

Partner Organization: Saskatoon Food Bank and Learning Center

Disclaimer: The purpose of this report is educational and does not substitute for professional services in any areas, including for example architectural, civil, legal, mechanical or health related design. This work was completed on a voluntary basis for the organization cited above. The work served the experiential learning component of a course entitled ENVS 992, offered in the School of Environment and Sustainability's Masters of Sustainable Environmental Management program. No obligations or liabilities are implied.

Executive Summary

The City of Saskatoon is challenged with large quantities of wood wastes such as demolition wastes, construction wastes, and elm tree trims. It has also been recently found that some of the elm trees in Saskatoon might have been infected with the Dutch elm disease, hence, this would lead to the cutting down of trees. The cutting of the affected elm trees will definitely increase the quantities of wood wastes in Saskatoon. The City of Saskatoon might therefore develop the initiative to develop more landfills, as all wood wastes are usually deposited into the landfills. Landfills are usually not environmental friendly, hence, no one wants a landfill in his backyard.

Furthermore, the concerns about climate change is also a pressing issue around the world as individual countries most especially the industrialised countries are looking for means to reduce their carbon foot prints. The two issues discussed above have therefore developed the initiatives for renewable energy sources as an alternative to the burning of fossil fuel to produce energy. One of the common alternatives to burning of fossil fuel is the biomass fuel specifically the woody biomass fuel (wood chips). This project is therefore developed as one of the initiatives to evaluate the feasibility of wood chips as an energy source in Saskatoon.

The essence of this project is to evaluate the financial viability of using wood chips (urban wastes) to produce heat energy in the Saskatoon Food Bank and Learning center's new complex. This is called a preliminary feasibilty report, which involves:

- Calculating the amount of heat required in the new building, to determine the annual amount of fuel consumption, and the amount of heat required during the coldest periods of the year.

- Determination of the annual cost of fuel, maintainance cost and the cost of implementing the project.
- Estimation of the effects of changes in the annual cost of natural gas on the profitability of using wood chips for energy, through a sensitivity analysis.
- Determination of the availability of biomass fuel (wood chips), to predict the potential for sustainable supply in the future.

The software used for the feasibility analysis is the retscreen software and is designed to be used for clean project analysis. Results from the analysis shows that even though the installation cost of a biomass heating system is very high, the project is still economically viable. The economic analysis suggest a pay back period of less than twenty years. These results show that the benefits of this project out weighs the cost. It is also important to note that when comparing the cost and amount of natural gas consumed annually, the generation of heat using wood chips is cheaper. The carbon dioxide mitigation analysis shows that there is less net carbon dioxide emission with the combustion of wood chips when compared to natural gas. It should be noted that carbon dioxide released during the harvesting, triming, and transportation of wood wastes are not accounted for in this analysis The sensitivity analysis result shows that an increase in the price of natural gas is positive for the project, as this would encourage the use of wood chips for energy. A basic supply chain model was developed for the food bank showing that the City of Saskatoon would be the major supplier of chips. The supply chain involves the transportaion of wastes from the landfill to the conversion site which is the Saskatoon food bank's new complex. The food bank will be in charge of the transportation cost, and might not have to pay for the wood chips if the City of Saskatoon is willing to supply the wood chips at little or no cost when considering the cost to the city of disposing the chips in the city landfill.

TABLE OF CONTENTS

List of Tables and Figures

List of Tables

List of Figures

Acknowledgement

I would like to express my deep gratitude to my research supervisors Tom Allen and Ken Belcher, for their patience, guidance, enthusiastic encouragement and useful critiques of this research work. I would also like to thank Dr. Vladimir, the MSEM program coordinator for the planning and his assistance in fulfilling my requirements for the MSEM program. My thanks also extend to Brit McDonald of the Saskatoon Food Bank and Learning center for showing enthusiastic interest in this project.

I would like to thank Joshua Quintal and Chris Richards of the Environmental and Corporate initiatives for their immense support, time and interest in this project. My special thanks also goes to Toso Bozic for his professional assistance.

Finally I wish to thanks my Parents, siblings, and Uncle Abayomi Akintola for their support and encouragement throughout my study.

1. Introduction

Renewable energy targets and subsidies on renewable energy projects have encouraged the burning of biomass for energy around the world, particularly in Europe and the United States of America (Wilson, 2014). Due to the concerns about climate change, which is contributed to through the burning of fossil fuel, the United States enforced a renewable energy policy at the federal level in 2005, to address the issues in the transportation sector (Carla & Alisha, 2105). In the electricity sector, the Renewable Portfolio Standards (RSP) has also been introduced, such that in an area, the amount of energy produced must include certain amount of renewable fuel resources (Carla & Alisha, 2015). However, Carla & Alisha (2015) noted that addressing the sources of heating and cooling as one of the “mitigating policies of climate change” has been less emphasized in the United States. In the Mediterranean area, such as; France, Greece and Spain, the Renewable Energy Sources (RES) policies have created favorable platforms, promoting the use of biomass for energy (Roque et al., 2014). The main focus of the RES project was to address the issues that prevent the development of sustainable energies in the participating countries. Finland, Sweden and Ireland are some of the countries leading the use of biomass for fuel energy because of the “positive developments in the forest industry sector” (Heinimö & Alakangas, 2009); Biomass fuel is well recognised as a fuel used in the heating sector, and between 1997 and 2010, about one hundred heating and combined heat and power plants were introduced in Finland (Heinimö & Alakangas, 2009). An important reason for the adoption of Renewable energy policies in industrialized countries has been to address climate change and the emission of carbon dioxide (CO_2). These countries are striving to fulfil their commitment to reduce their greenhouse gas emission under Kyoto agreement. Woody biomass therefore, is considered a valid alternative to the burning of fossil fuel around the world, as it currently serves ten per cent of the world's primary energy supply (IEA, 2015).

Canada is an industrialized country with high CO_2 emission, the government of Canada is therefore committed to reducing greenhouse gas emissions (GHG) (Douglas, 2010). Programs and policies have been developed since April 2007, new policies and programs have also been funded in 2010, and are directed towards:

a. Energy Efficiency: this program sets the standard for the production of energy efficient products like windows, doors, and thermostats. The use of these products influences the level of energy consumption by residents;
b. ecoEnergy for Technology Initiative: this program was funded to promote the research on development and demonstration of clean energy technologies;
c. ecoEnergy for Buildings and Houses: this program encourages the construction of energy efficient houses with energy labels;
d. ecoEnergy Retrofit Program: this program was developed to encourage energy efficient improvements to houses and organizations, and also to provide property grants of about $5000, for energy efficiency improvements, (Douglas, 2010).

Renewable fuel policies have also been implemented since 1990s' in the form of tax exemptions; there was also a policy stating that renewable content of 2% be included in diesels for transportation and heating (Douglas, 2010). Most of the government policies and incentives have been directed to the production of sustainable and environmentally friendly bio fuels, however, there has been minimal attention by the Canadian government to support biomass for heat and power (Douglas, 2010). The policies developed in 2010 were directed towards the production of ethanol and bio heat production (Douglas, 2010).

Canada is one of the world's largest exporters of wood products, as about 41% of the land is forested (Douglas, 2010). The provincial governments control about 77% of forestry land, while 16% is owned by the federal government and the remaining 7% is privately owned (Douglas, 2010). Provinces like British Columbia, Quebec, Ontario, New Brunswick, and Nova Scotia are very active in using woody biomass for energy and have implemented different renewable energy policies. British Columbia has the largest forest industry in Canada and was the first to develop a bio energy strategy including the development of a biomass inventory in 2008 and since then has been the leading province in terms of biomass projects in Canada. Quebec has the second largest forest industry, but has suffered from setbacks due to the reduction in annual harvest of wood, the increasing cost of the Canadian dollar, and the reduction in annual demand for lumber by the United States of America. However, according to Douglas (2010), in the past seven years, the province of Quebec has implemented some programs on innovative biomass system and converting natural gas heating systems to woody biomass, with financial grants allocated to such projects. Ontario has also been committed to reducing its GHG emissions, by setting renewable targets in 2004; out of the 20 biomass projects that were implemented, only about four projects were on biomass heat and power generations, (Douglas, 2010).

In Saskatchewan, there are very limited to no initiatives and reports on using biomass for generating heat and power. Jean & Berch, (2014) reported that in 2009, Saskatchewan had the smallest volume of harvested logs compared to other provinces, which can be attributed to the small amount of logged areas. However, it was not stated in the report what these harvested logs were used for. This limited harvest is partly because Saskatchewan has no specific policy for forest biomass and its utilization. The biomass harvesting industry in Saskatchewan is very small and privately owned, but with the involvement of the government, this industry can serve as the backbone for projects that involves using wood trims, wood wastes and wood residues for the production heat. According to Jean & Berch (2014), sources of woody biomass in Saskatchewan include residues from lumber mills and heritage piles; heritage piles are large stores of wood in mills, these constitute the primary sources. Road side residues from logging are the woods that are transported to the logging access road, after the harvesting of trees in the forest. The road side residues constitute the secondary source. Finally, wastes from silviculture and woods that are below the standard selling sizes in lumber markets represent the tertiary sources of woody biomass in the province. Other potential sources include wood wastes from urban construction and horticultural cutting.

There are very few policies and projects on using woody biomass as a source of heat and electricity in Saskatchewan. In 2011, Saskpower developed strategies for electricity production using woody biomass. Saskpower identifies biomass as an important source of energy because it is renewable, sustainable, and carbon neutral. However, the disadvantages listed in the report included limited quantities of biomass fuel, supply chain risk, the still developing state of boiler technology and particulate emissions apart from GHG. In the Minister's Task Force Report on Forest Sector Competitiveness (2006), the amount of recoverable harvest in Saskatchewan was estimated to be about 200,000 to 400,000 green tonnes per year. It was therefore recommended that Saskpower should design policies to encourage long term purchase of green electricity generated from woody biomass at a sufficient premium to encourage the profitable generation of electricity and heat. This recommendation was made following from the Minister's report which stated that the generation of electricity and heat using biomass is not profitable at the current electricity and heat prices.

2. Problem

An important source of heat around the world is through the burning of fuels like natural gas and coal. However, energy production using natural gas is cleaner and more efficient compared to coal. In Canadian homes, more than 50% of space heating and 65% of water heating uses natural gas as fuel (Natural Resource Canada, 2015). For Canadian businesses, 80% of water heating and space heating depends on natural gas as a fuel (Natural Resource Canada, 2015). Nevertheless, natural gas is non-renewable and produces gas emissions including carbon dioxide (CO_2) when consumed, which is part of the causes of climate change. Global climate change is now a major issue around the world and the industrialized countries are classified as the main emitters of GHG.

Woody biomass is said to be a very feasible alternative to natural gas for heat generation. Woody biomass may be considered a sustainable and viable alternative because in many locations it is readily available and it can regenerate in the natural environment. Woody biomass consists of trees and plant parts like branches, tops and leaves, and the residues of harvested trees, grown in the forests, woodlands and urban environments (USDA, 2013). By-products from sawmills are also an important source of wood biomass which are then converted into chips or pellets, to be used for space heating, electricity generation and cooking. In Saskatchewan, the volume of harvested biomass was estimated at about 1.8 million cubic meters (m^3) in 2009 (Jean & Berch, 2014). In the province, there is significant potential for the production of enough woody plant parts and residues for generating energy if the forests are sustainably managed. In Saskatoon alone, the amount of elm tree residues (wood chips) produced annually amounts to about 1,400 tones, which is primarily deposited into the landfills at a financial cost to the city. Alternative uses could be designed for these residues over the next few years, at very little to no cost for acquisition from the City of Saskatoon, except for the cost of transportation to the conversion site for energy generation. Although woody biomass is readily available, there could be inconsistency in moisture content that can lead to increasing handling cost to dry to acceptable moisture content and transportation cost to move the biomass to the combustion site (Jo, 2008). The normal heat value for wood chips is about 10 to 20 Green joules per tonnes (Gj/t), depending on the moisture (Jo, 2008). There is no standard price for wood chips in Saskatchewan, as there is no market for wood chips, therefore, it is possible that wood chips could be available for no or very low cost for sometime because the City of Saskatoon is trying to reduce the rate at which wood wastes such as elm tree residues and demolition wastes are deposited into landfills.

Another advantage of woody biomass when used for heat generation is that it can be considered carbon neutral. The CO_2 released during harvesting and combustion is partly from the fossil fuel burned by machineries during the harvesting of trees and also the carbon that was sequestered from the atmosphere by trees, through photosynthesis. The combustion of wood emits some particulate matter (PM), and the end product of combustion is the ash, which is not favorable to the air quality. In British Columbia, metropolitan Vancouver has proposed an amendment of a new air- quality management by-law, making woody biomass boiler users obliged to use advanced emission control systems that reduces PM emissions. This law does not exist in Saskatchewan however an equivalent law could be enacted and enforced in Saskatchewan at the stage when the production of heat using the biomass boiler system is widely recognized.

The utilization of biomass for heat generation is still very new in Saskatchewan. However, with the intention of the government to reduce its carbon foot print, the uncertain and potentially increasing cost of natural gas fuel, there is the potential that using biomass for energy would be embraced in the province. The essence of this project is to evaluate the financial viability of using woody biomass, which in this case constitutes urban wood wastes, for generating heat in the Saskatoon Food Bank and Learning Center's new complex. The steps involved in conducting a preliminary feasibility for this kind of project are explained in details in section 5.

3. Case Study Description

The Saskatoon Food Bank and Learning Center is a non-governmental organization that provides food for hungry people and is also involved in community development programs in the City of Saskatoon. In order to expand the scope of the operation, the food bank is planning to add to its facilities to encompass a much bigger site, which would include, as a component, a community greenhouse. The proposed community greenhouse would provide a setting from which to train the entire community. To help meet the mandate of the greenhouse, it has been designed such that the source of heat energy in the building is the combustion of woody biomass within a boiler system. According to the Saskatoon Food Bank and Learning Center, they have embarked on this project to:

- Decrease the cost of heating the building,
- Help the organization become who they want to be, by promoting community gathering,
- Sustainable energy demonstration, by setting up alternative uses for forest trims, and other woody residues, (MacDonald, 2014).

The sources of woody biomass for this project would be the urban forest trims and other woody residues available in Saskatoon. Current estimates show that the city of Saskatoon collects about

1,400 tonnes of elm tree residues annually, out of which the City of Saskatoon Parks pay for about 370 tonnes to be deposited in the City of Saskatoon landfill. The remaining1,030 tonnes constitute the wastes deposited by private companies involved in the trimming and chipping of elm trees from private residential property in the city. By diverting these residues from the landfill to be used for biomass generated heat, the city of Saskatoon would save about $135,000 in tipping fees (Josh Quintal, n.d.). Converting 370 tonnes of wood residues is equal to 3700 GJ thermal energy; this is equivalent to about $26,000 in Natural gas (Josh Quintal, n.d.). This is enough to heat one of the administrative buildings in the City of Saskatoon, because all the elm wood waste is equivalent to 14,000GJ if used for heating, and the City saves some costs (Josh Quintal, n.d.). Also, because of the concerns about the risk of spreading Dutch elm disease, the waste from elm trees must be kept separate, this represents not only safety issues but additional cost to taxpayers (Wicks & Anweiler, 2013). However, there have been very few studies on the alternative uses of the urban forest trims as a source of heat for urban buildings and facilities.

4. Literature Review

Using wood biomass for energy, most especially for cooking has a very long history, and was considered, until recent history, the major source of energy (Demirbaş, 2006). However, the discovery of fossil fuels around the world largely replaced the use of wood, since the industrial revolution took place in the 18th century. The combustion of fossil fuel contributes about 98% of the carbon emissions around the world (Demirbaş, 2006). However, from the perspective of solving environmental issues, discouraging the burning of fossil fuel would reduce the amount of carbon dioxide and environmental pollution. There are many studies on the development of renewable energies focusing on the technical and economic analysis, the logistics and supply chain analysis. These studies were completed in different countries; most of these studies were done in Europe, where renewable energies are well recognized. Each of these studies focused on different technologies such as direct combustion, gasification, and the combination of heat and electrical power generation.

Chau et al., (2009b), conducted a techno-economic analysis of wood biomass boilers for the greenhouse industry in British Columbia using wood pellet and wood residues to generate heat. The results showed that, based on calculated net present value, the installation of a wood pellet or wood residue boiler to generate 40% of heat annually is more efficient than using the natural gas boiler to generate 100% of the heat at a discount rate of 10%. The results also showed that 3,000 tonnes of CO_2 emissions can be removed annually, using the wood biomass boiler compared to the natural gas boiler.

Considering the fluctuations in price and cost of parameters for sound decision making, there is the need for sensitivity analysis to present the impacts of fluctuations in economic parameters. Chau et al., 2009a conducted a study on the Economic sensitivity of wood biomass utilization for greenhouse heating application. They extended their initial study by doing an assessment of the impacts of changes in prices of fuel, wood biomass energy contribution and the changes in the size of the greenhouse on the net present value of using wood pellet or residues as the fuel to produce heat, with or without the emission control mechanism. The results showed that an annual 3% increase in the price of fossil fuel, coupled with carbon taxes, and other policy instruments will increase the rate of using wood biomass by 20%, and doubling the size of a greenhouse will not affect the efficiency of a wood pellet or wood residue boiler.

A more detailed economic estimation of investment plans for a wood biomass system was completed by Ilias et al., (2007) who conducted an economic evaluation of biomass heating system using the case study of greenhouses in northern Greece. This paper enumerates the methods for evaluating the viability of investing in a biomass heating system. Ilias et al., (2007) presented the technical parameters involved in installing a biomass heating system, as well as the financial models used to verify the profitability of the investment plans. These parameters were applied to two case studies – greenhouse heating projects in Chalkidiki, northern Greece. The first case study was to evaluate the implications of installing a 900 kilo watt (KW) biomass system to heat a five acre greenhouse, and the second case study analyzed the installation of a 2 mega watt (MW) biomass combustion system to heat two opposite greenhouses of about 11 acres. Results showed that given a 40% subsidy of the initial cost, and the biomass fuel supplied at 50 euro per ton, the two projects are considered highly profitable, even when the subsidies were reduced by half, the two projects remained profitable. But with no subsidy in both cases, the projects were not attractive, even though there are long term benefits attached to the projects, this is because the initial cost of starting the project was very high (Ilias et al.,2007).

Instead of focusing on the financial aspect of installing a biomass plant; Rentizelas et al., (2009) conducted research on the logistics issues of biomass, especially the storage problem and the multi-biomass supply chain. "Multi biomass supply chain is the combination of different biomass chains to reduce capital costs" (Rentizelas et al., 2009). An example of the multi biomass concept is the combination cited by the author which involves the use of straw and reed canary grass, the combination of which resulted in a 15-20% reduction in cost, compared to using a single type of biomass (Nilsson, 2001). Storage and transportation cost constituted the main costs in using woody biomass for energy which was due to the seasonal variation in the quantity of woody biomass available for energy (Rentizelas et al., 2009). Using GIS modeling software, the writers analyzed three of the commonly used storage methods and then applied them to a case study for comparative results. The result of this research showed that the most cost effective solution to biomass storage was the multi biomass approach. This approach, when combined with expensive storage methods had lower cost. However, the major limitation of the multi biomass system approach was that the biomass boiler may not be capable of using the mixture of fuel for energy conversion.

It is anticipated that the rate of biomass utilization, especially woody biomass, will increase in the future. The demand for wood will therefore increase over the years. This would further complicate the woody biomass supply chain because wood is available in different locations in a region, and the low energy density nature of wood residues will require the transportation of large quantities to the conversion site. The energy density of wood is the amount of energy stored in the wood to burn; which is determined by its chemical and physical properties. Comparing liquid fuels to woody biomass fuel, the energy density of liquid fuel is higher. Therefore, for the woody biomass to produce heat, in the same amount as the liquid fuel, large quantities of wood chips would be required because of its low energy density. The transportation of which would require heavy duty vehicles, and burning of more fossil fuel, which results in the emission of CO_2 also known as carbon footprint. Hon et al., (2010), conducted research on reducing the amount of CO_2 emission, of a regional biomass supply chain. In this study, the case studies were divided into clusters, through the Regional Energy Clustering (REC) developed by the writers to reduce the system carbon footprints. In order to observe the nature and size of the energy clustering, Regional Energy Surplus-Deficit Curve (RESDC) was used. To detect any imbalance in making decisions in “trading off resources management,” Regional Resource Management Composite Curve (RRMCC) is used (Hon et al., 2010). According to the writers, the RRMCC is a composite curve that is used to provide direct and informative results for energy surplus/deficit planning and also for land use management (Hon et al., 2010). Hon et al., (2010), therefore concluded that these tools are used to provide direct information on the management of surplus resources.

In order to ensure a sustainable and cost-effective supply of woody biomass, to address the increase in future demand of woody biomass fuel, Dominik (2012), researched the operational efficiency of forest energy supply chains in different operational environment. The three dimensional approach was used to review the forest woody biomass supply chain from a technical, social, and economic point of view. According to the author, the three dimensional approach involves solving issues relating to forestry management and efficiency by categorizing these issues and solving them from the technical, economic and social dimensions (Dominik, 2012). This three dimensional approach was applied to four different case studies, operating in different environments to examine how this approach applies to improve the forestry efficiency. The author concluded that the three dimensional approach is very suitable to examine the relationship between the different aspects of a supply chain, that is, the type of technology, the stakeholders and parties involved in a supply chain. However, according to Dominik (2012), this approach is also suitable in the global perspective.

5. Research Objectives and Methods

The objectives and methods of this research are:

a. To analyze the economic feasibility of using woody biomass for heat generation.
b. To calculate the amount of carbon dioxide emission that would be mitigated, as a result of using the biomass boiler system for heat generation.

c. To calculate the effects of fluctuations in the prices of woody biomass on the net present value of the Saskatoon Food Bank heating system.
d. To inform the development of a steady supply chain model for the food bank. The implications of a supply contract between the food bank and the stakeholders will also be discussed.

Methods

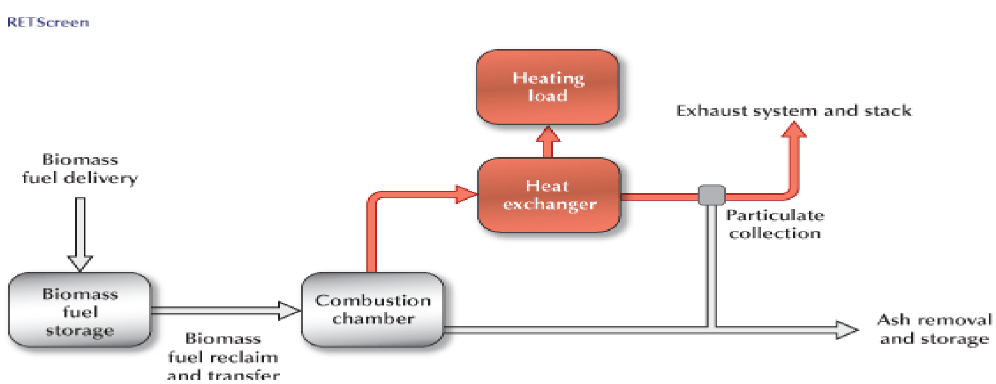
The methods enumerated below would be used to accomplish the objectives stated above.

a. To analyze the economic feasibility, the technical and economic analysis will be used to calculate the costs and benefits of using the woody biomass for heat generation.
b. To estimate the amount of CO_2 emissions mitigated in tonnes, the retscreen software will be applied for the main analyses in this project, and would also be used to determine this value.
c. To calculate the effects of price fluctuations, a sensitivity analysis will be conducted to determine the effects of fluctuations in the prices of feed stocks, on the net present value of the woody biomass project.
d. To inform the development of a robust and sufficient supply chain structure, and also determine the important stakeholders and the logistic factors that will be involved in the supply chain.

6. Biomass heating system

Biomass heating systems consume any woody residues in the form of chips, pellets, agricultural wastes, and demolition waste to generate heat. This heat can be transported through channeled pipes to where it is needed for ventilation or space heating. This process is called combustion and the technology used is called biomass boiler. The woody biomass boiler technology for producing heat is quite different from the conventional woody biomass burning system, such as the fireplaces in many residences. This is because the biomass boiler system is designed as an automated machine and the mixture of fuel and air is controlled to provide an efficient combustion that supplies a specific amount of heat and also to reduce emission. The diagram in Figure 1 details a biomass heating system. The biomass heating system consists of a heating plant, boiler system, and the biomass fuel which could be in the form of wood pellet or chips.

Figure1. Description of Biomass heating System



http://www.retscreen.net/ang/biomass_heating_system_description.php

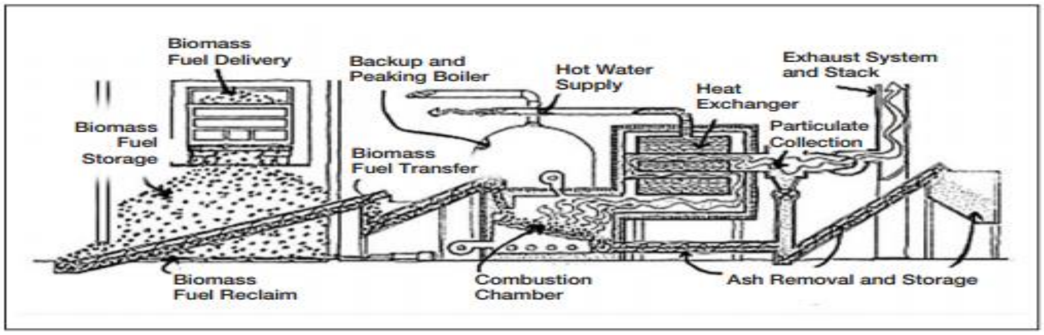
Biomass combustion system

The burning of fuel in the biomass boiler is called direct combustion. This involves some stages (See Figure 2) which are described by Natural Resources Canada (2005) as:

1. Biomass Fuel Delivery: this is the area where the fuel is received, and is usually located in the power site. This area is usually large enough for large delivery vehicles.

2. Biomass Fuel Storage: the storage area for biomass most especially wood chips is an open space in the outdoor, a shed with roof, or a large container with cover. The quantity of fuel must be enough to fire the biomass boiler for the period of time between deliveries.
3. Biomass Fuel transfer: this is the, automatic movement of biomass fuel from the storage into the combustion chamber. This process might necessarily not be automated. It could involve the manual loading of biomass fuel by the operator into the combustion chamber.
4. Combustion Chamber: it is in the combustion chamber that the biomass fuel is burned to produce heat under regulated conditions. The combustion chamber has been designed such that heat produced during combustion is kept inside the chamber. Hot air is released from the chamber into the chamber containing the heat exchanger.
5. Heat Exchanger: the heat released from the combustion chamber is transported to the heating channel through the heat exchanger. Heat exchanger could be in the form of boilers with water, steam or thermal oil as the mechanism to transfer heat.
6. Ash Removal and Storage: this is for the removal of ash, from the combustion chamber. The particulate matter emitted in the form of ash is removed from where it is suspended through the emission control mechanism. Particulate matters are released during the combustion of wood residues. The diagram below (Figure 2) shows a detailed illustration of a typical biomass combustion chamber.

Figure2. Biomass Combustion Chamber



Natural Resource Canada (2005)

7. Biomass heating techno economic analysis

As discussed in section 5, the purpose of this project is to conduct a preliminary feasibility study, to determine the viability of installing a woody biomass plant to generate heat in the new food bank complex. The essence of conducting this feasibility study is to:

- Calculate the heat demand required in the new complex, to determine the annual amount of fuel consumption, thermal peak and annual load;
- Determine the annual cost of fuel, annual cost of maintenance, and the total cost to implement the project;
- Estimate the effects of fluctuation in the prices of other close substitute fuels, on the value of the biomass fuel using a sensitivity analysis;
- Determine the availability of the biomass fuel, to predict the potential for an uninterrupted supply in the future.

The software that was used for these analyses is the retscreen software, designed for clean and environmental friendly project analysis. In the case of using the retscreen software to analyze a biomass project; the total cost of installation, energy production and the net reduction of greenhouse gases by installing the wood biomass heating system can all be estimated. Some technical and economic parameters were used to calculate the amount of heat production and the cost that would likely be incurred in the installation of a woody biomass plant. The first stage is the energy model phase, which calculates the amount of heat load needed to heat the building and the second stage would be to discuss the economic analysis, which is essential to show the financial cost and benefits of the project. This covers the first to the fourth objective of this project, as discussed in section 5.

7.1 Software design input data –

Tables 1and 2 below shows the required inputs for the technical and economic analysis; these are the software design inputs. The numeric values of each parameter are inserted so that the software calculates and presents the estimates to arrive at the goals stated in the table. These design inputs are presented on spreadsheets, and each of the analysis are separated in the individual work sheet.

a. Technical Components

Components	Parameters	Goals
Building site condition	• Heated floor area of the building • Energy efficiency measures • Heating load for the building	These inputs are used to estimate heating demand required in the building, and peak heating load. The peak heating load is the highest heating degree that will be

	• Domestic hot water heating demand base	required in the building during the coldest period.
Base case and Proposed case heating system inputs	• Fuel type • Fuel capacity • Seasonal efficiency of the heating system • Fuel cost	These inputs are used to estimate the total and annual costs of natural gas and the biomass heating system.
Peak load heating system	• Fuel capacity • Fuel type • Seasonal efficiency • Fuel cost	These inputs are used to estimate the total cost of a supporting heating system. This occurs when maximum heating degree is required and the proposed heating system does not have enough capacity.

b. Economic Components

Components	Parameters	Goals
Financial Parameters	• Inflation rate • Project life • Debt ratio	These inputs are used to determine the economic viability of the project.

	• Debt interest rate • Debt term	
Investment/Economic Evaluation	• Net present value • Simple payback • Benefit-Cost ratio	These inputs are used to project the profitability of installing a biomass boiler.

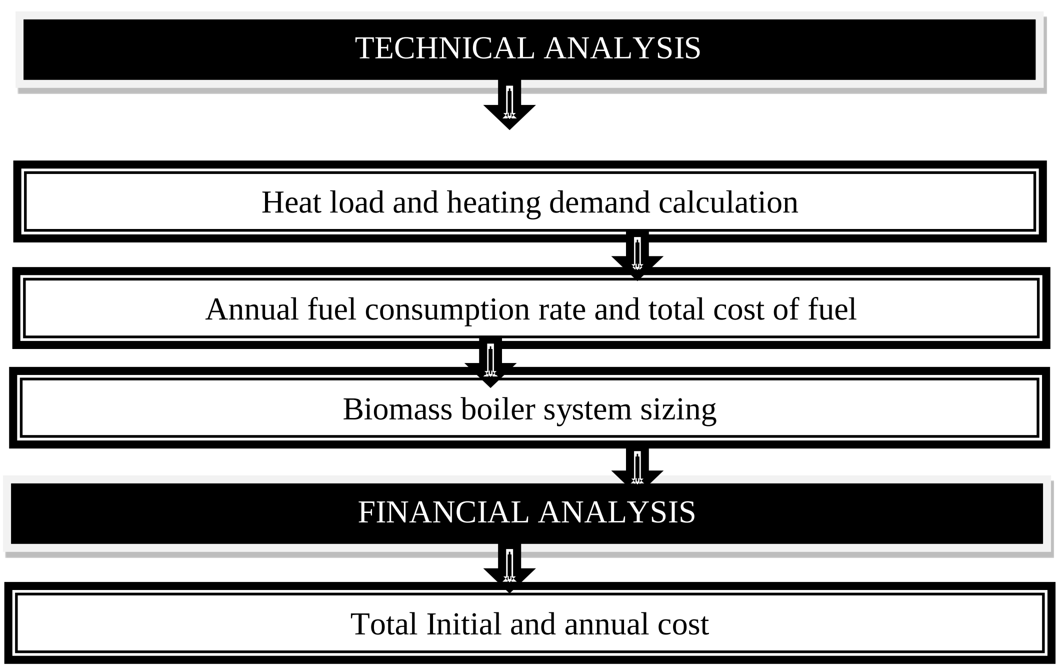
8. Application of the model to the case study

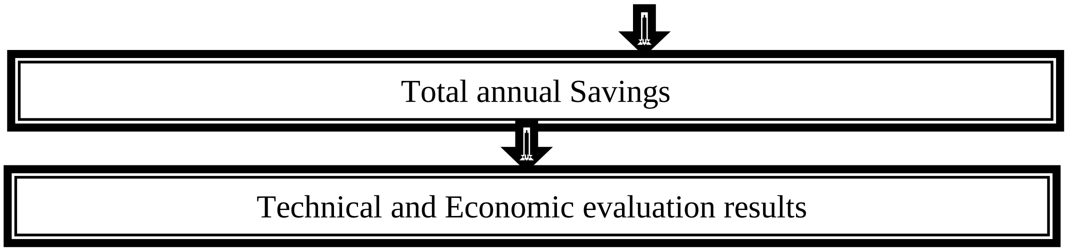
As described in section 3, the case study for this project is the Saskatoon Food Bank and Learning center. This case study focuses on heating the building of about 22,500 square foot (sq.ft.). The building would consist of offices and class rooms for community gatherings, while a larger proportion of the building would serve as the warehouse where food items are stored for distribution to people. The new complex is classified as above grade because it is a new building, the architects and engineers in charge will design the building in accordance with recent building design standards. It is anticipated that the insulation would be of a high standard. According to the Ontario Energy Codes 2012- Commercial and Residential, the R value for a commercial building depends on the heating degree days, and can range from R-22 to R-29. Therefore energy costs would be lower in the new building compared to the old food bank, such that there is a reduction in heat demand and the domestic hot water usage in the building.

8.1 Structure of the project

The data to be used for this project is presented in Tables 3 and 4 based on which the heating load for the building will be calculated, which is the input to estimate the heat demand required in the whole building. The total amount of heat required for the building and the annual cost of fuel would then be determined based on the seasonal efficiency of the fuel type and the heating value of fuel. The seasonal efficiency is used to determine the performance of the heating system over the service life of the system. The annual fuel consumption rate will also be estimated. These analyses constitute the technical feasibility of the project. The economic analysis would be conducted using the retscreen software, but presented separately in accordance with the system designed inputs. The inputs discussed in the previous section are the parameters to determine the total initial cost of the project and the expected annual savings for installing a biomass plant, when compared to the natural gas system of heating. This analysis would therefore generate the values for the economic evaluation parameters presented above. These parameters form the basis for evaluating the viability of incorporating the woody biomass heating system for the Saskatoon Food Bank and Learning Center. Figure 3 provides a summary of the steps to complete the project feasibility study.

Figure 3: Project flow chart





8.2 Main parameters/inputs-

This section explains in detail, the main parameters that are required to complete the calculations using the retscreen software, to calculate and present the required results to examine if the project is feasible or not. Most of the values of the parameters are based on representative estimates collected from the literature, as the case study for this project is not yet designed. These analyses represent a preliminary feasibility report, which sets the basis for a more complete report. The real feasibility report would be prepared by experts to be hired by the Food Bank, as soon as the site to build the new complex is developed.

8.2.1 Assumptions of technical analysis

- Building heating load

The Food Bank building is divided into different sections, the heating load required in each unit is calculated to determine the total heating load for the building. It is assumed that the new food bank complex would have three main sections, which are the greenhouse, offices and the warehouse. The heating load for each section is calculated by multiplying the area of each section in square meters (m^2), by the assumed normal temperature of each unit in watt/square meters (W/m^2). Figure

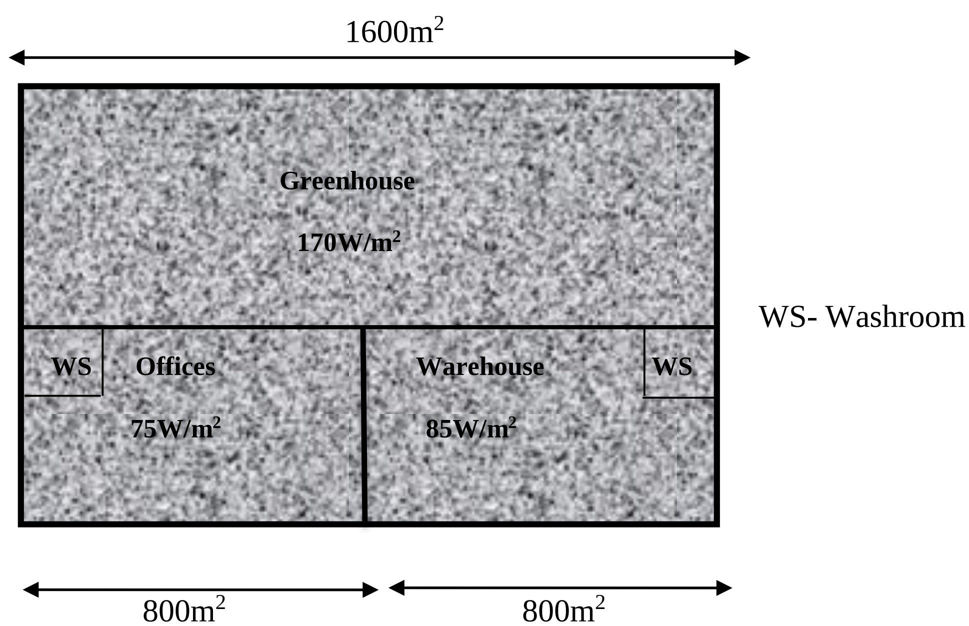
4 below illustrates the dimension of the new complex. According to Ilias et al.,(2007), to maintain the temperature of about 18 ^{O}C in a greenhouse requires the capacity of about 170W/m^2. The assumed heating energy requirement for the greenhouse used in the calculation is about 170W/m^2. The assumed heat capacity for the offices and ware house is about 75W/m^2 and 85W/m^2, respectively. Therefore, the heating load for the whole building is approximately 125W/m^2.

Building heat load calculation:

$$\frac{1600m^2(170\ W/m^2) + 800(75\ W/m^2) + 800(85\ W/m^2)}{3200m^2}$$

$$= 125W/m^2$$

Figure 4: The dimension of the new complex



- Domestic hot water heating demand

It is assumed that two to three washrooms would be in the building. The maximum hours spent by staffs in the building is less than twenty four hours, therefore the domestic hot water heating demand base is set at 0%. 0% means that very little to no hot water will be needed in the building. This assumption is based on the fact that the whole building would be composed of limited appliances, and based on the fact that the temporary occupants of the building might not visit the washrooms throughout their stay except for the staffs, who might need limited quantities of water for hygine purposes.

- Fuel type

The type of biomass fuel that is considered for this project is wood chips. Wood chips will be sourced from the elm tree trims, demolition wastes, and construction wastes. It is assumed that the heating value of these chips would be very high . The high heating value means that the wood fuel (chips) will produce high degree of heat when it is burnt (during combustion). This is because the tree trims and wood wastes are converted into chips, before they are deposited into the landfills, such that some of the moisture content in the trims amd wastes would have been reduced through evaporation, before they are transported to the conversion site.

- Seasonal efficiency

Seasonal efficiency is used to classify the performance standard of heating systems, throughout the heating season. The degree of efficiency all through the heating season includes the period of peak performance and the period when low heat is required (Timothy, 2004). The degree of seasonal efficiency depends on the rate of heat loss in a building. For this project, it is assumed that the seasonal efficiency is about 75%. This is based on the fact that the amount of heat loss will be reduced because the building would be designed according to the recent building design standards with good insulation. From the literature, the typical market seasonal efficiency of the biomass system is set at 55 to 65 percent (Timothy, 2004)

- Biomass system capacity

The stated maximum capacity of the heating system required for this project is about 200kilo Watt (KW). This value was suggested by Bill Swan, who is one of the experts involved in this project.

- Fuel Rate

The unit of fuel in this analysis is $30 CAN/t (Canadian dollars/tonne). This cost was determined based on the literature on the prices of wood chips in different provinces in Canada and the United States. This cost is very low compared to other costs. It is also anticipated that at the commencement of this project, the cost of wood chips might be lower than this value. The City of Saskatoon will be the main supplier of wood fuel and may be willing to get rid of all the wood wastes at little or no cost to the Food Bank. The only cost that would be incured on these chips would be the transportation cost, of delivering the chips, which would be paid by the food bank.\

Table 3: Energy model inputs

Site condition	
Floor area size	3205.1549 m^3
Heating load for the whole building	125 W/m^3

Domestic hot water heating demand base	0%
Biomass system	
Fuel type	Wood chips
Seasonal efficiency	75%
Biomass system capacity	200KW
Fuel cost	$30 CAD/t

8.2.2 Assumptions for Economic Analysis

This section explains the cost and financial analysis inputs; and also presents the value of economic parameters that can be used to forecast that profitability of the project.

- Unit cost of heating system

The unit cost of the heating system is the estimated cost of heating with woody biomass in Canadian dollars per watt. A cost of $3/watt is used in this report, based on the cost suggested by the engineers involved in the Saskatoon Food Bank project (Bill Swan, n.d).

- Training and Commisioning

This is the total cost of training operators and the biomass boiler maintenance personnel. Commisioning involves testing the newly acquired equipment to guarantee that it is in good working order over a stated period of time. The amount depends on the machinery type and other technical factors depending on the equipment manufacturers. The value of about $45,500 is used for this project as presented by FINK Machine INC. (Stephen Bearss, n.d).

- Fuel cost escalation rate

This parameter is the projected average percentage increase in the price of natural gas and the price of the biomass fuel throughout the project life time. The assumption made for this project is that both the cost of natural gas and wood chips would increase annually by about 1.1%. this value is based on the literature, as there is no record of fuel cost escalation rate for wood chips, and considering the fact that in the past few months, there has only been a slight increase in the price of natural gas. However, the price of wood chips is assumed to be constant.

- Fuel system handling cost

For this project, fuel system handling cost includes the cost of silo loading, fuel storage, and fuel extraction; the total cost of which is about $55,446 was presented by FINK Machine INC (Stephen Bearss n.d.). This is the value that is used in the analysis, as FINK Machine INC is assumed to be the supplier of the woody biomass boiler for this project. Usually, the fuel system handling cost of a biomass system depends on the type and size of the equipment.

- Inflation

This is the projected average inflation rate over the life time of the project. The value of the inflation rate used for this project was determined by considering the average inflation rate over the past five years (2010 to 2015). The average value of 1.68% annually is used in the analysis. It should be noted that the Canada inflation rate used was released by statistics Canada (Inflation Calculator, 2015).

- Discount rate

The retscreen model uses the discount rate to present the annual savings costs in investing in the biomass project, throughout the project life. It is used to discount the future cash flow to present the net present value of the project. The rate used for this project is 3.00%, which is the current prime rate used in Canada. The current prime rate means the interest rate charged by commercial banks to its best credit consumers. This rate is not consistent with the rate used in similar project, this is because most of these projects are executed in different countries.

- Project life

The expected project life used in this analysis is 25 years.

Table 4: Cost and Financial analysis inputs

Cost analysis	
Unit cost of heating system	CAD $3/watt
Training and commissioning	CAD $45,500
Fuel system handling	CAD $55,446
Financial analysis	
Fuel cost escalation rate	1.1%
Inflation rate	1.68%
Discount rate	3.00%
Project life	25 years

8.3 Main outputs and discussion

Table 5 presents the results of the technical analysis conducted using the retscreen software. The estimated total heat demand is the assumed amount of heat that would be required to keep the building at the target temperature, such that the occupants are comfortable. The estimated temperature for a commercial buildings in Canada is about 18^{O}C (HVAC,n.d). The estimated value of about 125W/m^3 would be required in the building. The peak heating load is the heat required in the building during the coldest period of the year. The estimated peak heating load is about 400.6KW, however, the maximum capacity of the boiler considered for this project is 200KW, and as a result, this analysis assumes that there would be a need for backup heating system in the coldest periods of the year to meet the peak heating load required. Based on these values the estimated amount of wood chips consumed annually is about 211 tonnes, the total cost of wood chips is therefore estimated to about $6,342.00 annually.

Table 5: Main outputs of the technical analysis

Technical Analysis	
Total heating demand	125W/m3
Peak heating load	400.6 KW
Annual fuel consumption	211 tonnes
Total annual cost of fuel	CAD $ 6,342.00

Table 6 presents the main results of the economic analysis. The total estimated initial cost of installation of the biomass boiler is about $382,162.00. It is important to note that this cost does not include the construction cost, transportation of the boiler to the Food Bank site, spare parts and other miscellaneous expenses. About $600,000 is assumed to be the budget for this project (Bill

Swan, n.d), therefore, about $217,838 or more is assumed to cover the remaining costs that are not included in the analysis. In the analysis, no provision was made for receivable grants and credits that might be involved in the project. The estimated installation cost of $382,162.00 is therefore determined by considering the cost of the biomass boiler, training and commissioning, and fuel handling system.

Table 6: Main outputs of financial analysis

Economic analysis	
Total initial cost of installation	CAD $ 382,162
Total annual cost	CAD $ 6,342
Total annual saving	CAD $ 31,205

Table 7 reports the overall financial analysis of the project. From the results presented in the technical analysis, it is important to note that when comparing the cost and the amount of natural gas and wood chips consumed annually, the consumption of wood chips is less expensive alternative to meet heating requirements. From the results presented in the financial analysis, the total annual savings presented is about $31,205, which is the annual cost of consuming natural gas, if the natural gas boiler is used to produce heat. From the results presented in table 7, this project may provide a relative net benefit. This is because some financial parameters like debt term and interest rate are still missing from the results. However, the net present value is positive and the benefit cost ratio is greater than one, meaning that the benefits of this project out weighs the cost. The cost of installing the woody biomass heating plant is an important component of the costs of this system. The results presented in the analysis also shows that there is the payback period of about 15.4 years.

Table 7: Economic evaluation/financial viability

Economic evaluation	
Simple payback	15.4 years
Net Present Value (NPV)	CAD$ 110,207
Annual life savings cost	CAD$ 6329
Benefit-Cost ratio	1.29

9. Sensitivity analysis

Sensitivity analysis is used to examine how sensitive an output is to any changes in the value of any input in the financial feasibility report. For this project, the sensitivity analysis is conducted to determine the effects of changes in the annual cost of natural gas, which in the software is represented as fuel cost- base case, and the effects of the changes in the annual cost of wood chips, represented as fuel cost- proposed case in the software. In this sensitivity analysis, changes in the cost of natural gas and biomass fuel impacts on the initial cost, which is also presented in the result sheet. The analysis therefore presents the overall effects of these changes on the net present value of using wood chip biomass fuel. The sensitivity analysis here is conducted using retscreen software, whereby the performance analysis is focused on the net present value of this project. The sensitivity analysis is based positive and negative changes in input values at the level of 15%, 25% and 50% compared with the base case at 0%, for the annual cost of natural gas, and the annual cost of wood chips, for this project. The threshold value for the financial indicator is set such that any value below the presented net present value indicates that the project is not financially viable. The table showing the sensitivity analysis results for each range is in appendix 7 of this report, and the software highlights the non-viable results in orange.

The sensitivity analysis results shows that the economic viability of this project is influenced at all levels by increases in the cost of the biomass fuel, which in the result sheet is presented as the fuel cost- proposed case. In the case where biomass fuel increase by 25% and 50%, the net present values of the project are negative. The unit price of wood chips at these levels are $38 to $45; however, it is anticipated that the prices of wood chips may not rise to these levels in Saskatoon. The City of Saskatoon might be willing to provide wood chips for free for some time, or even sell them at very low prices to encourage the use of renewable fuels, and to also get rid of all wood wastes instead of depositing the wastes in the landfills.

In the case of the changes in the annual cost of natural gas, in all the sensitivity ranges, the project is still viable. The scenario with 50% increase in natural gas cost, shows the net present value of the project was $228,102, which is the best case in the analysis. Since natural gas is a close substitute for wood chips, it was anticipated that an increase in the price of one of these fuel types, while the price of the other commodity remains unchanged or constant, would increase the demand for the latter commodity; and might even encourage the use of this commodity, which in the case of this project is the wood chips.

10. Biomass emission mitigation analysis

The model that was used for the techno economic analysis was also used to estimate the net amount of Greenhouse Gas (GHG) emission reduction. The values presented in the model are based on the input values of the parameters in the techno economic analysis. It is assumed that there is no GHG credit fee charged on the amount of carbon dioxide emission for this project. The estimate presented in the model compares the base case, which involves the generation of heat using the conventional method, and the proposed case which is the woody biomass system. The differences reported in Table 8 represents the amount of GHG emission mitigated by the biomass heat project. The net annual GHG emission reduction was 200 tCO_2(tonnes/CO_2) per year, meaning that the woody biomass system emits significantly less CO_2 during the combustion, and is far less than that of the natural gas. It should be noted that while conducting this analysis, some emissions were not accounted for. These excluded emissions where the gases released by machineries used for harvesting trees, chipping the wood wastes and tree trims, and the gases released during the transportation of the tree trims and wastes. Including these missing components will definitely increase the net emissions, as all the processes involved in harvesting, chipping and transportation involves the burning of fossil fuel. This adds to the value of the emission released in the proposed case, but might necessarily not be as high as that of the base case, because the whole process involved in the base case including the combustion involves the burning of fossil fuel.

Table 8: Emission analysis output

Base case annual emissions	tCO2	207.7
Proposed case annual emissions	tCO2	7.8
Net annual GHG emission reduction	***tCO2***	***200.0***

11. Supply chain analysis

The woody biomass supply chain is a series of procedures that involves the movement of biomass from the harvest stage to the end use stage. There are four interrelated phases involved in a biomass supply chain. According to Tanja et. al., (n.d.) the four interrelated phases are:

- Procurement and logistics which involves the harvesting and transportation of logs to the processing location. In the context of this project, the demolition wastes, construction wastes, and elm tree trims are converted to chips and then transported to the conversion site, this is considered as the logistics phase.
- Feedstock to bio energy conversion and distribution- involves the conversion of the logs and other biomass materials (urban wastes) to chips as discussed above, and the distribution of the chips to different conversion sites where they are needed. It is important to note that for this project, the cost of biomass feed stocks, which is the wood chips, is determined by the cost of fuel consumed during transportation to the conversion site, and the mositure content which determines the drying time. The cost of feedstocks might also vary depending on the energy market in each region, the cost of labour, and the cost of hring a machine or vehicle.
- The last stage in the biomass supply chain is the end use. This involves the conversion of wood chips to produce heat, at the conversion sites. According to FAO 2010, the economic sustainaility of woody biomass energy has four criteria:
    a. Beneficial Use – this is used to ensure that urban wastes and tree trim are used to produce wood fuel. If this is going to be a threat by spreading the Dutch elm

disease in Saskatooon, then using the elm trees for wood fuel might be discouraged;

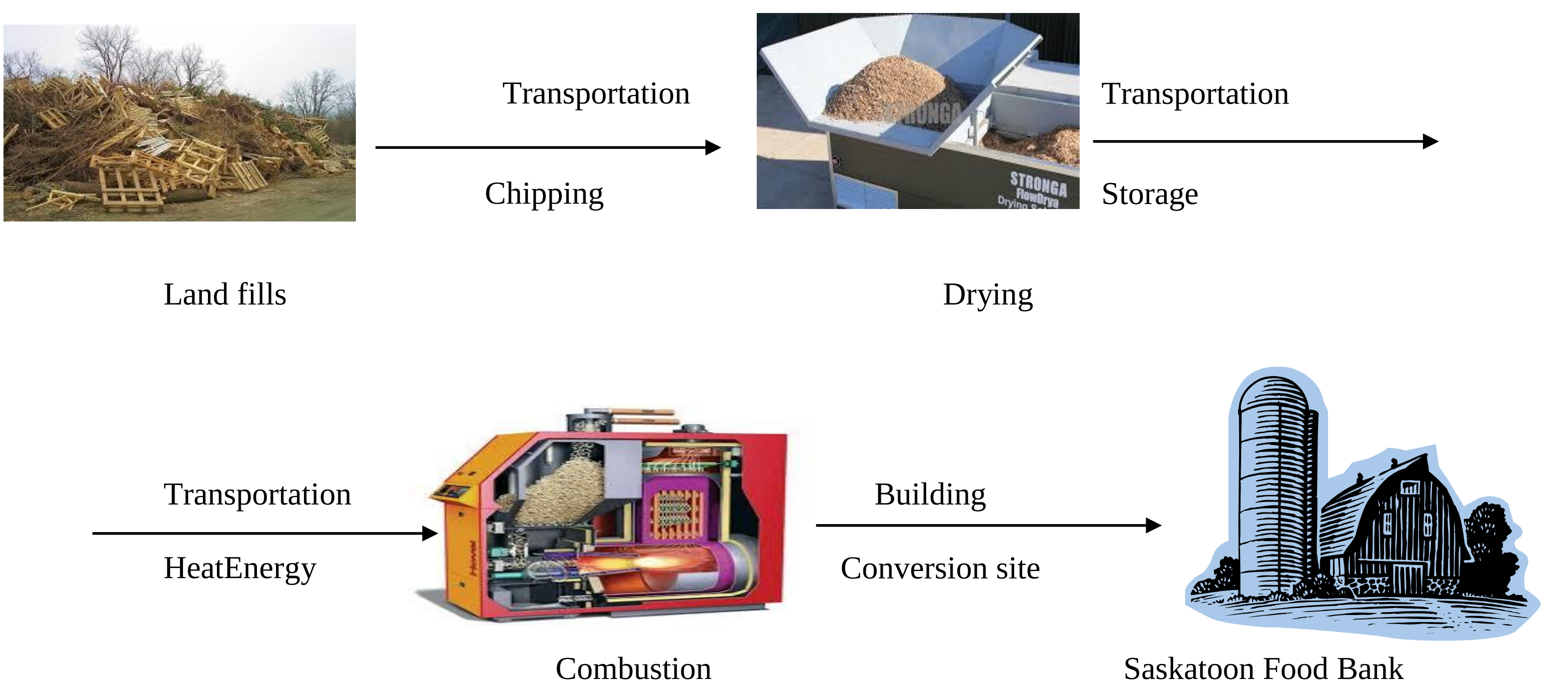
b. Economic viability – this is to ensure that the production of bio fuels has both the long term and short term viability. This is measured in terms of the profitability, when all the costs and benefits are accounted for;

c. Economic equity – this involve the equitable distribution of benefits among all the stakeholders involved in the woody biomass supply chain. For example, in the case of this project, the main stakeholders are the City of Saskatoon and the Food bank. The City would benefit from this project because there would be reduction in the quantity of wood trims and urban wastes that are transported to the land fills, and the Food bank will benefit by successfully operating a renewable heat energy system, and saving them a portion of the costs and expenses associated with the natural gas system of producing heat.

d. Property right and landowner expectations – these are laws that are passed to guide or regulate the harvest of wood and over harvesting of trees in the forest. In Saskatoon, this applies to the laws associated with the proper handling of elm trees, to prevent the spreading of the Dutch elm disease.

In designing the feed stock supply chain for the food bank, the criteria and indicators discussed above must be followed. However, the supply chain here is not as complicated as the case of fully developed market for wood fuels. Presently in Saskatoon, the main sources of wood fuels are elm tree trims, demolition wastes, and construction wastes. All these are usually chipped at a cost by the City of Saskatoon and are deposited into the landfills. The essence of this project is therefore to create an alternative use for these chips, by diverting the wastes from the landfills to the Saskatoon food bank and learning center’s new complex. The main stakeholders to be involved in the contract are the City of Saskatoon and the Food bank. The Saskatoon food bank might be responsible for the cost of transportation from the land fills to the conversion site. This to the food bank would constitute the transportation cost/the cost of acquiring wood chips. The supply chain procedures for the food bank would include the drying of the chips as the landfills are not covered. The drying of the chips could be in an oven, which would impose an additional cost to the food bank. The chips can also be deposited into a storage area, and be left to dry for sometime, before the chips are later used for combustion.

Figure 5: A basic supply chain model for the food bank



12. Conclusions

This paper presents a preliminary feasibilty report for the Saskatoon Food Bank and Learning Center, on the implications of using the woody biomass system as a source of heat rather than the conventinal natural gas heating system. Due to the concerns about climate change, which is caused by the burning of fossil fuel, there is the need to develop renewable and clean energy systems. Woody biomass is therefore considered as a feasible and sustainable alternative to burning of fossil fuel. Before the installation of a woody biomass boiler system, it is important to determine the long term and short term costs and benefit analysis. This is important to determine the viability and the profitability of a project before embarking on the project. The determination of the viability and profitability of this project is therefore presented in this preliminary feasibility report. This report is considered preliminary because the actual feasibility study would be conducted by the trained experts, when the site to develop this project is ready.

The methodology used in presenting this paper involves using the retscreen software model to calculate the estimated technical & financial analysis ,the biomass emission mitigation analysis and a sensitivity analysis. A basic supply chain model was also presented in the report. The retscreen software is used because it is user friendly and is designed for calculating clean energy project analysis for engineers.

The results presented in the technical and financial analysis shows that the installation of a woody biomass boiler plant is an important component of the overall cost of the system. However, the net present value of this project is positive, with an annual life saving cost of about $6,329. The total annual cost of woody biomass fuel was estimated at $6,342 which is lower than the annual cost of natural gas fuel of about $31,205, with a simple pay back period of about 15.4 years.

From the results presented in this report, it is imporatnt to note that the peak heating load that would be required during the coldest period of the year is about 400.6KW, but the maximum capacity of the boiler system required is about 200KW. This means that the new building might require a back up heating system. The biomass emission mitigation analysis shows a net annual GHG emission reduction of about 200 $tC0_2$ meaning that the woody biomass system emits significantly less $C0_2$.

The sensitivity analysis results shows that an increase in the annual cost of natural gas, which is a subsititute for wood chips increases the financial viability of the project. An increase in the price of natural gas to produce heat, considering the ranges used during the analysis, while holding constant the price of wood chips will reduce the demand for natural gas, and will encourage the use of wood chips for heating.

A basic supply chain was presented for the food bank, and the important stakeholders involved in the supply contract are the City of Saskatoon as the major supplier of wood chips, and the Saskatoon Food Bank, as the consumer of the wood chips.

Finally, The results of the analysis done in this project are just estimates of what to expect when the real feasibility report is conducted. This is because some parameters were missing while doing the calculations, and these parameters when included by the experts would change the values of the outputs presented in report. However, the biomass heating system has lower annual cost, compared to the natural gas heating system.

References

Aguilar, C., White, D., & David, R. (2005). *Domestic hot water heating and water heater energy consumption in Canada.* Canadian building energy end use. Data and analysis center.

Amit, K., Jay, B. C., & Flynn, P. C. (2003). Biomass power cost and optimum plant size in western Canada. *Biomass and Bioenergy 24, Issue 6* , 445-464.

Carla, S., & Alisha, F. (2015). Light My Fire: The Use & Policies of Woody. *Sustainable Development Law & Policy15, no.1* , 41-49, 62-64.

Demirbaş, A. (2006). Global Renewable Energy Resources. *Energy Sources, Part A: Recovery, Utilization, and Environmental Effects,28:8* , 779-792.

Dominik, R. (2012). *Operational efficiency of forest energy supply chains in different operational environments.* Finland: Finnish Society of Forest Science, Finnish Forest Research Institute, Faculty of Agriculture and Forestry of the University of Helsinki, School of Forest Sciences of the University of Eastern Finland.

Douglas, B. (2010, September 15). *Canada Report on Bioenergy 2010*. Retrieved August 18, 2015, from Climate Change Solutions: http://www.canbio.ca/upload/documents/canada-report-on-bioenergy-2010-sept-15-2010.pdf

Energy, Mines and Resources Canada (n.d.). Heating Ventilation and Air Conditioning. *Energy Management Series 10 for industry, commerce and institutions* , pp. 1-133. http://www.nrcan.gc.ca/sites/oee.nrcan.gc.ca/files/pdf/commercial/password/downloads/EMS_10_heating,ventilation_and_air.pdf

FAO (2010)Food and Agricultural Organization.*Criteria and indicators for sustainable wood fuel.* Rome. http://www.fao.org/docrep/012/i1673e/i1673e00.htm

FEMP. (2014, October 23). *Whole Building Design Guide*. Retrieved August 15, 2015, from Biomass for heat: http://www.wbdg.org/resources/biomassheat.php

Heinimö, J., & Alakangas, E. (2009). *MARKET OF BIOMASS FUELS IN FINLAND.* Finland: Lappeenranta University of Technology (LUT) and Technical Research Centre of Finland (VTT.

Hon, L. L., Petar, V., & Jiří, K. (2010). Minimising carbon footprint of regional biomass supply chains. *Resources, Conservation and Recycling 54:5* , 303-309.

IEA. (2015). *Renewables.* Retrieved July 15, 2015, from International Energy Agency: https://www.iea.org/topics/renewables/subtopics/bioenergy/

Ilias, J. G., Yiannis, A. K., & Pavlos, S. G. (2007). Economic Evaluation of Biomass Heating Systems: a Case of Greenhouses in Northern Greece . *Entgetpqotct~'Epe9vct / Operational Research. An International Journal Vol.7, No 1* , 83-104 .

Inflation Calculator. (2015). Retrieved September 17, 2015, from 2015 CPI and Inflation rate for Canada: http://inflationcalculator.ca/2015-cpi-inflation-canada/

J, Chau, T. Solwati, S. Sokhsnsanj, F. Preto, S. Melin, & X. Bi, (2009a). Techno-economic analysis of wood biomass boilers for the greenhouse industry. *Applied Energy* , 364-371.

J. Chau, T. Solwati, S. Sokhansanj, F. Preto, S. M elin, & X. Bi, (2009b). Economic sensitivity of wood biomass utilization for greenhouse heating application. *Applied Energy* , 616-621.

Jean, R., & Berch, S. M. (2014). *A Compilation of Forest Biomass Harvesting and Related Policy in Canada. Prov. B.C.* . Victoria. www.for.gov.bc.ca/hfd/pubs/Docs/Tr/Tr081.htm: B.C. Tech. Rep. 081.

Jo, C. (2008). *Evaluation of wood biomass utilization for the greenhouse industry in british columbia* . Vancouver: the university of british columbia .

Kittas, K., Gigalaras, P., & Koutra, A. (2002). Greenhouse heating with biomass in the prefecture of Magnesia. *National Conference for RES*, (pp. 169-176).

Nilsson, D., & Hansson, P. (2001). Influence of various machinery combintion fuel proportion and storage capacities on cost for co-handling of straw and reed camary grass to district plants . *Biomass and Bioenergy* , 247-60.

NRC (2001-2005). Biomass Heating Project Analysis Chapter. *CLEAN ENERGY PROJECT ANALYSIS:RETSCREEN® ENGINEERING & CASES TEXTBOOK* (pp. 5-47). Natural Resources Canada: http://www.retscreen.net/ang/biomass_e_textbook_chapter.php

NRC. (2008, October 10). *Natural Resources Canada*. Retrieved August 16, 2015, from Biomass Heating System Description : www.retscreen.net/ang/biomass_heating_system_description.php

NRC. (2015, July 17). *The Government of Canada.* Retrieved August 10, 2015, from Natural Resources Canada: North American Natural Gas Market, 2014-2015 heating outlook http://www.nrcan.gc.ca/energy/sources/natural-gas/16781

Ontario Energy Codes 2012- Commercial and Residential (2011, July 1). *Supplementary standard SB-10,Energy Efficiency supplement* , p. 6 http://logixicf.com/media/library/documents/Tech%20Bulletin%2034%20-%20Ontario%20Energy%20Codes%2020124fda581f50a8c.pdf

Quintal, J. (n.d.). *Elm wood diversion.* Saskatoon: City of Saskatoon.

R. Saidur, E.A. Abelaziz, A. Demribas, M.S. Hossain, & S. Mekhilef. (2011). A review on biomass as a fuel for boilers. *Renewable and Sustainable Energy review* , 2262-2289.

Rentizelas, A. A., Tolis, A. J., & Tatsiopoulos, I. P. (2009). Logistics issues of biomass: The storage problem and the multi-biomass supply chain. *Renewable and Sustainable Energy Reviews* , 887-894.

Roque, P. P., David, S. C., Ignacio, L. V., Pilar, A. L., Frenando, P. M., & Jose, P. D. (2014). *Promotion of residual forestry biomass in the Mediterranean Basin.* Marseille: International Association of Mediterranean Forests .

A personal communication with Bill Swan and Stephen Bearss, from FINK machine INC; and Brit MacDonald, of the Saskatoon Food Bank

Soon-Hong, K., In-bok, L., Kyeong-seok, K., & Taehwan, H. (2014). Assessment of heating load of greenhouse with GSHP system using BES technique. *International Conference of Agricultural Engineering* (pp. 1-7). Zurich: www.eurageng.eu.

Tanja, I., Antti, A., Robert, P., Inge, S., Tat, S., & Roser, D. (n.d). *Economic sustainability of biomass feedstock supply*. IEA Bioenergy.

Timothy, M. M. (2004). *Wood-Chip Heating Systems- A Guide For Institutional and Commercial Biomass Installations.* Vermont: Biomass Energy Resource Center, Montpelier. pg 31.

Trading Economics. (2015). Retrieved September 17, 2015, from Canada Interest rate: http://www.tradingeconomics.com/canada/interest-rate

USDA. (2013, March 29). *US Forest Services - Woody Biomass Utilization.* Retrieved August 10, 2015, from USDA: http://www.fs.fed.us/woodybiomass/whatis.shtml

Wicks, J., & Anweiler, D. (2013). *Elm gasification feasibility study for City of Saskatoon* . Saskatoon: Saskatchewan Research Council.

Williams, C. (n.d.). *Wisconsin Grasslands Bioenergy Network*. Retrieved September 15, 2012, from The biomass supply chain : http://www.wgbn.wisc.edu/biomass-supply-chain

Wilson, R. (2014, April 23). *Biomass: The World's Biggest Provider Of Renewable Energy*. Retrieved July 10, 2015, from The Energy Collective : www.theenergycollective.com/robertwilson190/370286/biomass-worlds-biggest-provider-renewable-rnergy

http://america.aljazeera.com/articles/2015/4/20/a-city-goes-renewable-but-raises-questions-about-imact-of-biomass-power.html

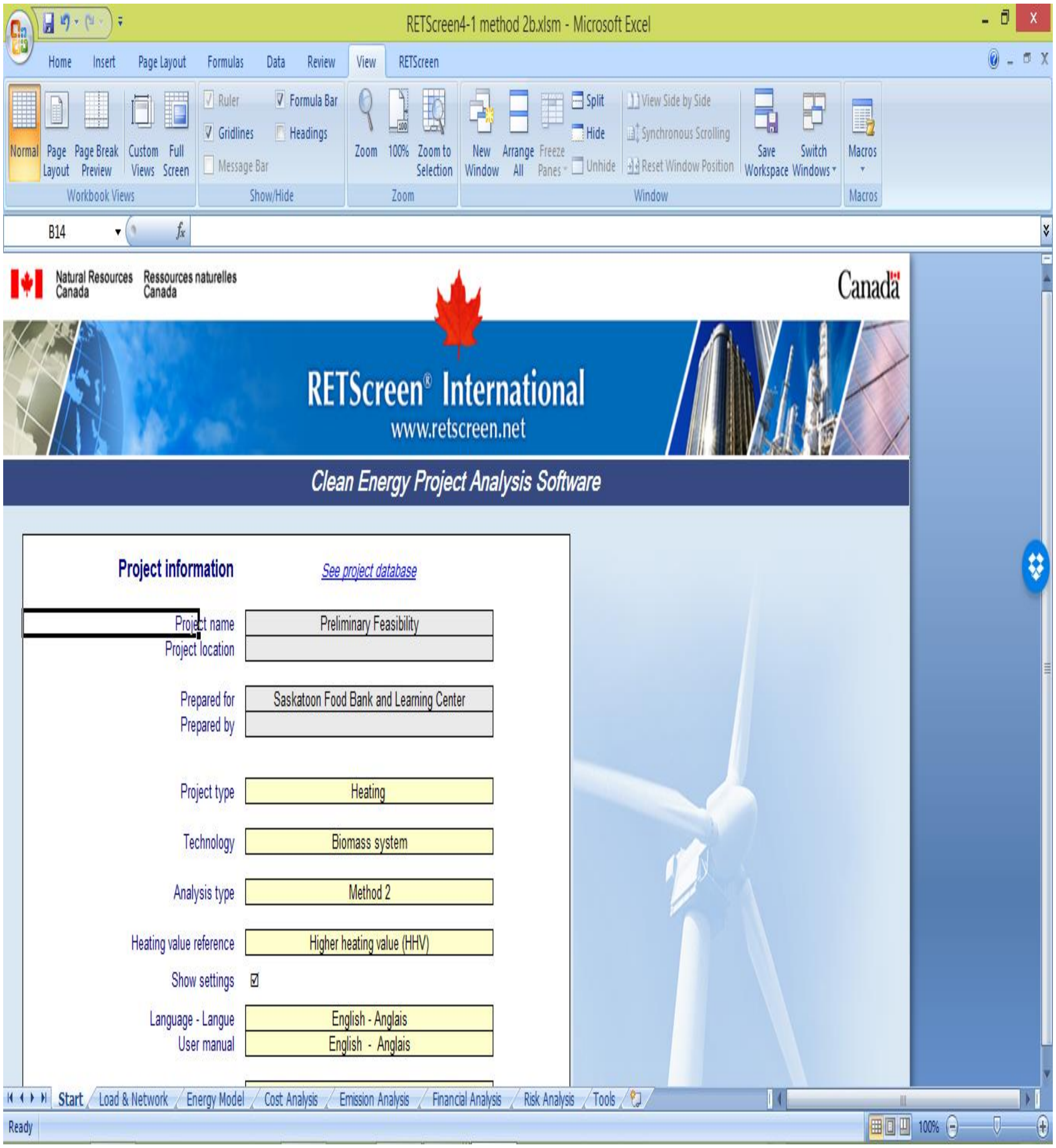
http://www.biomassinnovation.ca/biomassheat.html

http://www.inflation.eu/inflation-rates/canada/historic-inflation/cpi-inflation-canada-2015.aspx

http://www.stronga.no/2015/08/stronga-drying-solutions-renewable-biomass-fuel-from-drying-woodchip/

Appendices

Appendix 1



Appendix 2

RETScreen Load & Network Design - Heating project

Heating project	Unit		
Base case heating system		Single building - space heating	
Heated floor area for building	m^2	3,205	
Fuel type		Natural gas - m^3	
Seasonal efficiency	%	75%	
Heating load calculation			
Heating load for building	W/m^2	125.0	
Domestic hot water heating base demand	%	0%	
Total heating	MWh	870	
Total peak heating load	kW	400.6	
Fuel consumption - annual	m^3	111,447	
Fuel rate	CAD/m^3	0.280	
Fuel cost		CAD	31,205
Proposed case energy efficiency measures			
End-use energy efficiency measures	%	0%	
Net peak heating load	kW	400.6	
Net heating	MWh	870	

Appendix 3

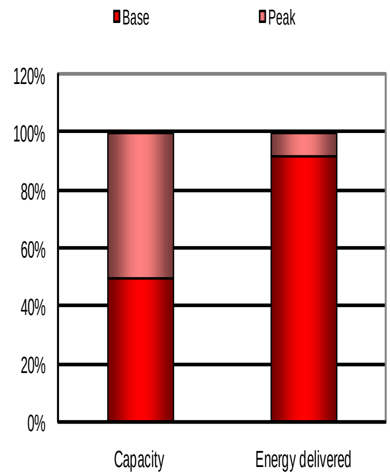
RETScreen Energy Model - Heating project

☐ Show alternative units

Proposed case heating system				
System selection	Base load system			
Base load heating system				
Technology	Biomass system			
Fuel selection method	Single fuel			
Fuel type	Biomass			
Fuel rate	CAD/t	30.000		
Biomass system				
Capacity	kW	200.0	49.9%	See product database
Heating delivered	MWh	798	91.6%	
Manufacturer				
Model				
Seasonal efficiency	%	75%		
Boiler type		Hot water		
Fuel required	GJ/h	1.0		

Proposed case system characteristics	Unit	Estimate	%
Heating			
Base load heating system			
Technology		Biomass system	
Capacity	kW	200.0	49.9%
Heating delivered	MWh	798	91.6%
Peak load heating system			
Technology		Boiler	
Fuel type		Biomass	
Fuel rate	CAD/t	30.000	
Suggested capacity	kW	200.6	
Capacity	kW	200	49.9%
Heating delivered	MWh	72.7	8.3%
Manufacturer			See PDB
Model			
Seasonal efficiency	%	75%	
Back-up heating system (optional)		Peak load not met	
Technology			
Capacity	kW		

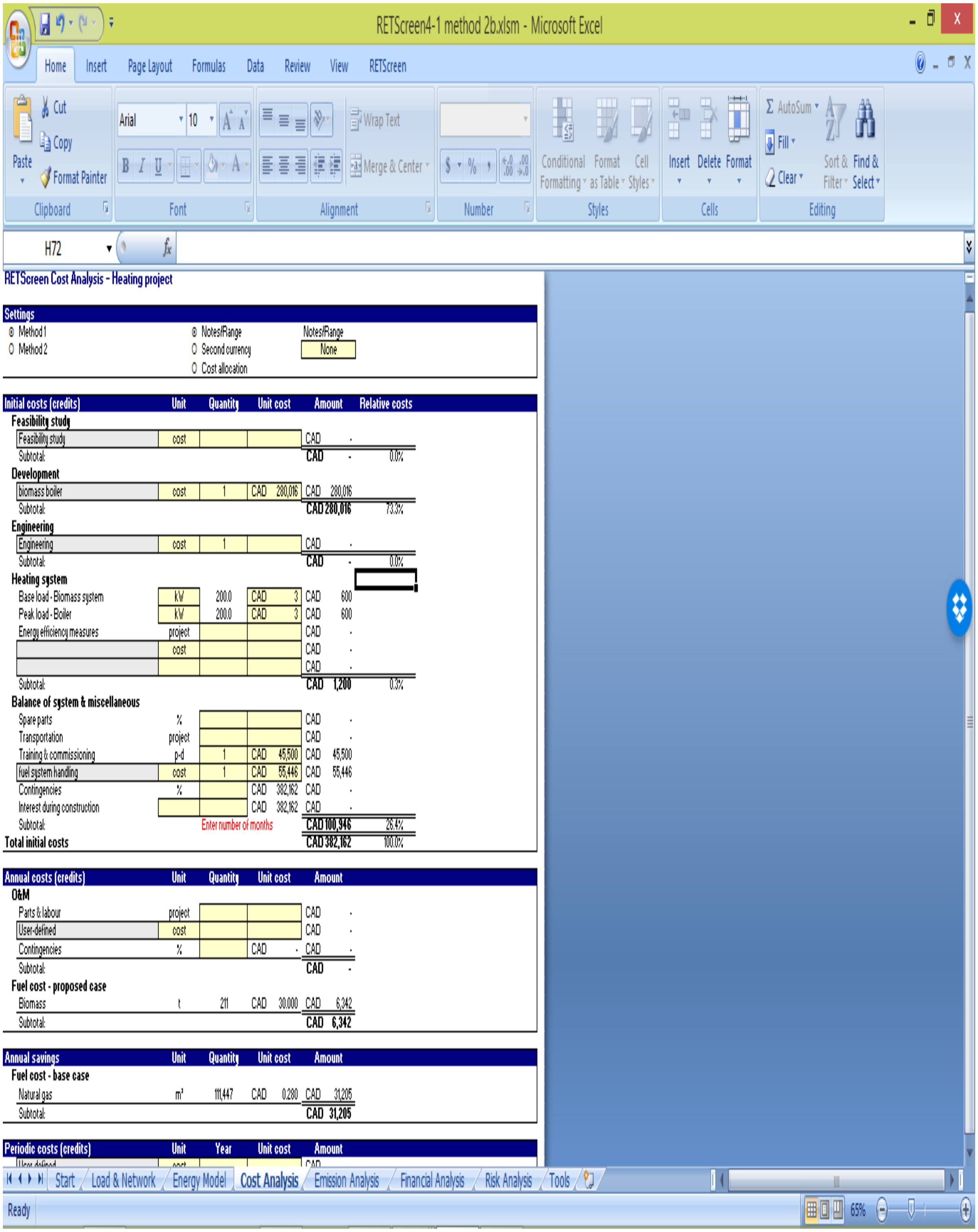
System design graph



Proposed case system summary	Fuel type	Fuel consumption - unit	Fuel consumption	Capacity (kW)	Energy delivered (MWh)
Heating					
Base load	Biomass	t	194	200	798
Peak load	Biomass	t	18	200	73
			Total	**400**	**870**

Complete Cost Analysis sheet

Appendix 4



RETScreen4-1 method 2b.xlsm - Microsoft Excel

RETScreen Cost Analysis - Heating project

Settings		
Method 1	Notes/Range	Notes/Range
Method 2	Second currency	None
	Cost allocation	

Initial costs (credits)	Unit	Quantity	Unit cost	Amount	Relative costs
Feasibility study					
Feasibility study	cost			CAD -	
Subtotal:				CAD -	0.0%
Development					
biomass boiler	cost	1	CAD 280,016	CAD 280,016	
Subtotal:				CAD 280,016	73.3%
Engineering					
Engineering	cost	1		CAD -	
Subtotal:				CAD -	0.0%
Heating system					
Base load - Biomass system	kW	200.0	CAD 3	CAD 600	
Peak load - Boiler	kW	200.0	CAD 3	CAD 600	
Energy efficiency measures	project			CAD -	
	cost			CAD -	
				CAD -	
Subtotal:				CAD 1,200	0.3%
Balance of system & miscellaneous					
Spare parts	%			CAD -	
Transportation	project			CAD -	
Training & commissioning	p-d	1	CAD 45,500	CAD 45,500	
fuel system handling	cost	1	CAD 55,446	CAD 55,446	
Contingencies	%		CAD 382,162	CAD -	
Interest during construction			CAD 382,162	CAD -	
Subtotal:		Enter number of months		CAD 100,946	26.4%
Total initial costs				CAD 382,162	100.0%

Annual costs (credits)	Unit	Quantity	Unit cost	Amount
O&M				
Parts & labour	project			CAD -
User-defined	cost			CAD -
Contingencies	%		CAD -	CAD -
Subtotal:				CAD -
Fuel cost - proposed case				
Biomass	t	211	CAD 30.000	CAD 6,342
Subtotal:				CAD 6,342

Annual savings	Unit	Quantity	Unit cost	Amount
Fuel cost - base case				
Natural gas	m³	111,447	CAD 0.280	CAD 31,205
Subtotal:				CAD 31,205

Periodic costs (credits)	Unit	Year	Unit cost	Amount

Appendix 5

RETScreen Emission Reduction Analysis - Heating project

☑ Emission Analysis

- ⦿ Method 1
- ○ Method 2
- ○ Method 3

Base case system GHG summary (Baseline)

Fuel type	Fuel mix %	Fuel consumption MWh	GHG emission factor tCO2/MWh	GHG emission tCO2
Natural gas	100.0%	1,161	0.179	207.7
Total	100.0%	1,161	0.179	207.7

Proposed case system GHG summary (Heating project)

Fuel type	Fuel mix %	Fuel consumption MWh	GHG emission factor tCO2/MWh	GHG emission tCO2
Biomass	100.0%	1,160	0.007	7.8
Total	100.0%	1,160	0.007	7.8

GHG emission reduction summary

	Base case GHG emission tCO2	Proposed case GHG emission tCO2	Gross annual GHG emission reduction tCO2	GHG credits transaction fee %	Net annual GHG emission reduction tCO2
Heating project	207.7	7.8	200.0		200.0

Net annual GHG emission reduction	200	tCO2	is equivalent to	36.6	Cars & light trucks not used

Complete Financial Analysis sheet

Appendix 6

RETScreen Financial Analysis - Heating project

Financial parameters

General		
Fuel cost escalation rate	%	1.1%
Inflation rate	%	1.1%
Discount rate	%	3.0%
Project life	yr	25
Finance		
Incentives and grants	CAD	0
Debt ratio	%	0.0%
Income tax analysis		☐

Annual income

Electricity export income		
GHG reduction income		☐
Net GHG reduction	tCO2/yr	200
Net GHG reduction - 25 yrs	tCO2	4,999
Customer premium income (rebate)		☐
Other income (cost)		☐

Project costs and savings/income summary

Initial costs			
Development	73.3%	CAD	280,016
Heating system	0.3%	CAD	1,200
Balance of system & misc.	26.4%	CAD	100,946
Total initial costs	**100.0%**	**CAD**	**382,162**
Annual costs and debt payments			
O&M		CAD	0
Fuel cost - proposed case		CAD	6,342
Total annual costs		**CAD**	**6,342**
Periodic costs (credits)			
Annual savings and income			
Fuel cost - base case		CAD	31,205
Total annual savings and income		**CAD**	**31,205**

Financial viability

Pre-tax IRR - equity	%	5.3%
Pre-tax IRR - assets	%	5.3%
After-tax IRR - equity	%	5.3%
After-tax IRR - assets	%	5.3%
Simple payback	yr	15.4
Equity payback	yr	14.1
Net Present Value (NPV)	CAD	110,207
Annual life cycle savings	CAD/yr	6,329
Benefit-Cost (B-C) ratio		1.29
GHG reduction cost	CAD/tCO2	(32)

Yearly cash flows

Year	Pre-tax	After-tax	Cumulative
#	CAD	CAD	CAD
0	-382,162	-382,162	-382,162
1	25,137	25,137	-357,025
2	25,413	25,413	-331,612
3	25,693	25,693	-305,919
4	25,976	25,976	-279,943
5	26,261	26,261	-253,681
6	26,550	26,550	-227,131
7	26,842	26,842	-200,289
8	27,138	27,138	-173,151
9	27,436	27,436	-145,715
10	27,738	27,738	-117,977
11	28,043	28,043	-89,934
12	28,351	28,351	-61,583
13	28,663	28,663	-32,920
14	28,979	28,979	-3,941
15	29,297	29,297	25,357
16	29,620	29,620	54,976
17	29,945	29,945	84,922
18	30,275	30,275	115,197
19	30,608	30,608	145,804
20	30,945	30,945	176,749
21	31,285	31,285	208,034
22	31,629	31,629	239,663
23	31,977	31,977	271,640
24	32,329	32,329	303,969
25	32,684	32,684	336,653

Appendix7

RETScreen Sensitivity and Risk Analysis - Heating project

☑ Sensitivity analysis

Perform analysis on	Net Present Value (NPV)	
Sensitivity range	2%	
Threshold	110,207	CAD

				Initial costs		CAD
Fuel cost - base case		374,519	378,340	382,162	385,984	389,805
CAD		-2%	-1%	0%	1%	2%
30,581	-2%	105,491	101,669	97,847	94,026	90,204
30,893	-1%	111,670	107,849	104,027	100,205	96,384
31,205	0%	117,850	114,028	**110,207**	106,385	102,563
31,517	1%	124,029	120,208	116,386	112,564	108,743
31,829	2%	130,209	126,387	122,566	118,744	114,922

				Initial costs		CAD
Fuel cost - proposed case		374,519	378,340	382,162	385,984	389,805
CAD		-2%	-1%	0%	1%	2%
6,215	-2%	120,361	116,540	112,718	108,897	105,075
6,278	-1%	119,106	115,284	111,462	107,641	103,819
6,342	0%	117,850	114,028	**110,207**	106,385	102,563
6,405	1%	116,594	112,772	108,951	105,129	101,307
6,469	2%	115,338	111,516	107,695	103,873	100,052

RETScreen Sensitivity and Risk Analysis - Heating project

☑ Sensitivity analysis

Perform analysis on	Net Present Value (NPV)	
Sensitivity range	10%	
Threshold	110,207	CAD

				Initial costs		CAD
Fuel cost - base case		343,946	363,054	382,162	401,270	420,378
CAD		-10%	-5%	0%	5%	10%
28,085	-10%	86,627	67,519	48,411	29,303	10,195
29,645	-5%	117,525	98,417	79,309	60,201	41,093
31,205	0%	148,423	129,315	**110,207**	91,098	71,990
32,765	5%	179,320	160,212	141,104	121,996	102,888
34,326	10%	210,218	191,110	172,002	152,894	133,786

				Initial costs		CAD
Fuel cost - proposed case		343,946	363,054	382,162	401,270	420,378
CAD		-10%	-5%	0%	5%	10%
5,708	-10%	160,981	141,873	122,765	103,657	84,549
6,025	-5%	154,702	135,594	116,486	97,378	78,269
6,342	0%	148,423	129,315	**110,207**	91,098	71,990
6,659	5%	142,144	123,035	103,927	84,819	65,711
6,976	10%	135,864	116,756	97,648	78,540	59,432

RETScreen Sensitivity and Risk Analysis - Heating project

☑ Sensitivity analysis

Perform analysis on	Net Present Value (NPV)
Sensitivity range	15%
Threshold	110,207 CAD

Fuel cost - base case		Initial costs				CAD
		324,838	353,500	382,162	410,824	439,486
CAD		-15%	-8%	0%	8%	15%
26,524	-15%	74,838	46,176	17,514	-11,148	-39,811
28,865	-8%	121,184	92,522	63,860	35,198	6,536
31,205	0%	167,531	138,869	**110,207**	81,544	52,882
33,546	8%	213,877	185,215	156,553	127,891	99,229
35,886	15%	260,224	231,561	202,899	174,237	145,575

Fuel cost - proposed case		Initial costs				CAD
		324,838	353,500	382,162	410,824	439,486
CAD		-15%	-8%	0%	8%	15%
5,390	-15%	186,368	157,706	129,044	100,382	71,720
5,866	-8%	176,950	148,287	119,625	90,963	62,301
6,342	0%	167,531	138,869	**110,207**	81,544	52,882
6,817	8%	158,112	129,450	100,788	72,126	43,463
7,293	15%	148,693	120,031	91,369	62,707	34,045